The Space Congress® Proceedings

1995 (32nd) People and Technology - The Case For Space

Apr 26th, 2:00 PM - 5:00 PM

Paper Session II-A - International Space Station Alpha Payload Accommodations

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Canaveral Council of Technical Societies
32nd Space Congress
Cocoa Beach, Florida
April 25, 26, 27, 28, 1995

INTERNATIONAL SPACE STATION ALPHA PAYLOAD ACCOMMODATIONS

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Abstract

The International Space Station Alpha (ISSA) is a low Earth orbiting research facility to conduct microgravity, life science, earth observations, astrophysics, new technology, and commercial experiments. This paper provides an overview of the ISSA payload accommodations supporting these research disciplines.

The ISSA supports payloads in a pressurized and unpressurized environment. A shirt sleeve working condition is provided to payloads in the United States Laboratory, the Centrifuge Module, the Japanese Experiment Module, the European Columbus Orbiting Facility, and three Russian Research Modules. Payloads are physically and functionally integrated within the ISSA via the International Standard Payload Rack, standard drawers, and Shuttle common middeck lockers. External payloads are provided accommodations on the U.S. integrated truss, the Japanese Exposed Facility, and the Russian Science Power Platform.

The types of resources and systems that support these payloads include 120 Vdc power, low, medium, and high rate data management systems, video distribution, low and moderate thermal water loops, vacuum access for exhausting contaminants, and various gases. The ISSA also supports ground control of payloads and reception of research data via a world-wide uplink and downlink communications system.

The International Space Station Alpha (ISSA) is a low Earth orbiting facility for conducting research in the life science, microgravity, earth observations, astrophysics, space processing, and engineering disciplines. The ISSA will be assembled on-obit at an altitude of 220 nautical miles with contributions from the United States, Canada, Japan, the European Space Agency, and Russia. The ISSA provides a shirt sleeve environment for conducting research in the US Laboratory (US Lab), the Centrifuge Module, the Japanese Experiment Module (JEM), the European Columbus Orbiting Facility (COF), and three Russian Research Modules. The Mini Pressurized Logistics Module (MPLM) provided by Italy serves as a conditioned pressurized transport carrier to replenish and return passive and perishable payload cargo. External Earth observations can be performed by utilizing the payload attachment points on the Integrated Truss Assembly, the JEM Exposed Facility, and the Russian Science Power Platform. The pressurized and external locations are equipped with a variety of electrical, avionics, fluids, and gas interfaces to support the experiments. ISSA solar arrays, thermal radiators, communication system, propulsion, environmental control, and robotic devices provide the infrastructure to support sustained research.

This paper reflects the design maturity of data regarding payload accommodations at the time of its submittal (2/15/95). The ISSA configuration is shown in Figure 1. As the design matures (qualification tests of components and associated analyses of the integrated performance are updated), the ISSA Payload Accommodations Customer Documentation Tree will be updated accordingly.

PRESSURIZED ACCOMMODATIONS

International Standard Payload Racks in the US Lab, COF, and JEM. To support efficient integration and interchangeability of payload

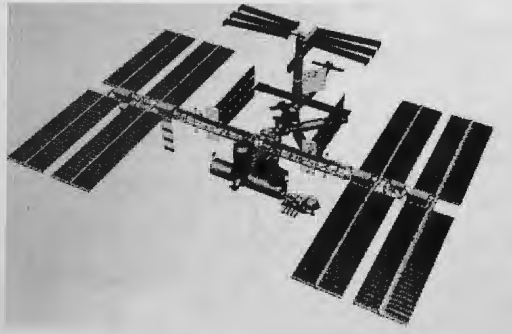

Figure 1. ISSA Configuration

hardware and to maximize joint research between the users of this multi-national facility, the program has adopted the International Standard Payload Rack (ISPR). There are 33 ISPR slots on ISSA (13 in US Lab, 10 in JEM, 10 in COF) which provide a common set of interfaces regardless of location. Additionally, non-standard services are provided at selected locations to support specific payload requirements.

Structural and Mechanical. The ISPR provides 55.5 cubic feet of internal volume for payloads. Its configuration is shown in Figure 2. The rack weighs 230 pounds and can accommodate an additional 1543 pounds of payload equipment. The rack has internal mounting provisions to allow attachment of secondary structure. The ISPRs will be outfitted with a thin center post to accommodate sub-rack payloads, such as the 19" Spacelab Standard Interface Rack (SIR) Drawer or the Space Shuttle middeck locker. Utility pass-through ports are located on each side to allow cabling between racks. Module attachment points are provided at the top of the rack and via pivot points at the bottom of the rack. The pivot points support installation and maintenance. Seat tracks on the exterior front posts allow mounting of payload equipment and laptop computers. Additional adapters on the ISPRs are provided for ground handling.

Figure 2. ISPR Configuration

Power. The standard power interfaces for the 33 ISPRs consist of a 3 kW power feed and a 1.2 kW safing feed. The power interface voltage will range from 114.5 to 126 Vdc. Prime power is fed to the ISPRs via 8 gauge wiring. The modules provide the switching and circuit protection using 25 Ampere remote power controllers. The safing power feed is distributed on 12 gauge lines. At selected ISPR locations (5 in the US Lab, 3 in the COF, and 3 in the JEM), a 6 kW power capability is distributed on 4 gauge wiring along with 1.2 kW safing feed. At three locations within the US Lab, prime and redundant 6 kW power feeds are provided to support furnace and combustion operations.

Command and Data Handling. The standard interfaces to the ISPRs include a Mil-Std-1553B protocol using twisted shielded wire pairs and a high rate data link via optical fibers. Commanding of payloads from the ground, crew, and on-board automated procedures is accomplished using the 1553 bus. Health, status, safety, and ancillary data types are also communicated over the 1553 bus. Each payload location is allowed one remote terminal on the bus. Payload display and controls via seven laptop ports are supported in the three modules (4 in US Lab, 2 in COF, and 1 in JEM). A timing signal is available to the payloads at 1 hertz with an accuracy of +\- 5.0 milliseconds with respect to the onboard time source over the 1553 bus. Each ISPR is provided 2 fibers which connect to an input and output port on the automated payload switch for distribution of up to 100 Mbps of data between racks or for downlinking via the Ku-band system. An 802.3 Ethernet local area network is distributed to the ISPR locations within the US Lab for telemetry, file transfer, and lap top communications. The 10Base-T Ethernet architecture allows 10 Mbps of data transfer to multiple ISPR locations.

Video. The standard video interface to the ISPRs within the US Lab and the COF is via fiber optic lines using an EIA-RS-170A optical pulse frequency modulated video signal. Fibers are used to support video to and from the ISPR payload. A synchronization and control signal is also provided to the ISPR in accordance with EIA-RS-170A. The video distribution to the JEM is via twisted shielded wire pairs. A common video interface unit (CVIU) will be used inside the payload racks to convert the optical PFM video/sync signals to electrical baseband NTSC EIA-RS-170A video/sync. The electrical baseband signal from the CVIU is available via a single ended or differential interface. The video signals from the ISPRs are sent to switches which allow distribution to onboard monitors, video tape recorders, or to the video baseband signal processor to allow distribution to the ground via the Ku-band. Four video tape recorders are provided with cassettes capable of recording payload video (with time tagging) for two hours. The implementation of video within the JEM is under review to ensure video commonality. Options include adding a switch to support fiber optic distribution or adding circuitry within the CVIU to convert twisted shielded pairs into coax.

Thermal. A moderate temperature water loop is provide via a 1/2" line with a quick disconnect to each ISPR at an inlet temperature range of 61-75 °F. The water is circulated through heat exchangers and stainless steel coldplates to allow the thermal conditioning of internal payload hardware. The water flow is controlled within the US Lab and the JEM to optimize the rejection efficiencies of the system. The maximum return water temperature is 122 °F. Internal to a payload rack, an avionics air/heat exchanger assembly can be connected to the loop to remove up to 1200 Watts by circulating air. At selected locations with in the US Lab (9 ISPRs), the JEM (5 ISPRs), and the COF (2 ISPRs), a low temperature water loop (33-50 °F) is provided via a 1/2 " line with a quick disconnect. The maximum return temperature on this loop is 75 °F. A pressure drop of 5.8 psid is allowed across the inlet and outlet of both water loop interfaces. Additionally, payloads may dissipate a small amount of heat into the cabin air. While depending on the temperature conditions set by the crew, a minimum of 600 Watts can be dissipated into both the US Lab and COF (complement of all payloads with the module). Negotiations are underway with NASDA on the allowable heat dissipation into the JEM.

Vacuum Exhaust System (Waste Gas). A 1.0" waste gas line with a quick disconnect is provided as a standard interface to the 33 ISPRs. Each partner's module contains the plumbing to vent directly to space. The design pressure allowed into the waste gas line is 40 psi. The temperature of the exhaust waste gas is allowed to be between 60-113 °F. The waste gas system is capable of reaching a pressure of 1×10^{-3} Torr in less than two hours for a single payload volume of 100 liters at an initial pressure of 14.7 psia. Automated valves (controlled by the ISSA systems) are provided within the US Lab and JEM. The valves to be used in the COF (manual or automated) are under review. The waste gas system is a shared and scheduled resource among the ISPR payloads (operation of only one ISPR location in that module at a time). This is to prevent cross contamination of payloads and incompatible mixtures of waste gas constituents. The types of waste gas constituents are under review (and will likely be determined on a case by case basis and documented in the payload unique interface control document).

Vacuum Resource. At selected locations within the US Lab (9 ISPRs), the JEM (4 ISPRs), and the COF (10 ISPRs), a 1.0" vacuum resource line is provide via a quick disconnect for those payloads requiring a vacuum environment. Each partner's module contains the plumbing to support this service to space. The US Lab and COF valves for this operation are manual. The vacuum is provided at a pressure of 10^{-3} Torr. Multiple payload locations may be connected to the vacuum resource at a time.

Nitrogen. A 3/8" nitrogen line via a quick disconnect is provided as a standard service to all 33 ISPRs. The nitrogen is provided between 63-85 °F at a pressure of 80-120 psia. The flow rates to payloads will be up to 0.6 lbm per minute. The payload will incorporate a valve to control the flow of nitrogen.

Carbon Dioxide, Argon, and Helium. As a non-standard interface, carbon dioxide, argon, and helium are provided to selected ISPR locations in the JEM. These gases are provided via a 3/8" line with a quick disconnect. The nominal pressure range of these gasses are 75-114 psi when a single ISPR is being operated. The maximum design pressure of the line is 200 psi.

Fire Detection and Maintenance Switch Assembly. Discrete lines are provided to ISPRs from the C&DH command and control processors to allow feedback of smoke/fire detection signals. A rack maintenance switch with indicator is provided to shut off power to the rack to allow payload servicing within the rack. A fire hole will be provided by the payload where a credible fire risk exists for connection to a module provided portable fire extinguisher.

EXPRESS Rack. The ISSA is providing an EXPRESS rack capability to accommodate shuttle middeck lockers and Spacelab Standard Interface Rack drawers. EXPRESS rack allows for rapid (11 month) integration into the ISSA. The rack provides a 15 SIR drawer configuration or a mix of 8 middeck lockers with two SIR drawers. The units are equipped with a 120 Vdc to 28 Vdc converter and provide 500 W (total of 2 kW aggregate) to payloads. Avionics air and a moderate temperature loop are provided. Several types of data interfaces are made available (RS 232, RS 422, IEEE 488, Ethernet, analog, and discretes). Video is also accommodated at all payload sites. Vacuum exhaust and nitrogen are provide at the utility panel and may be used serially by payloads.

Nadir Window. A nadir viewing window is located in the floor of the US Lab for sensor and camera type payloads. The window has a 20" clear aperture with a viewing angle of 20 degree half cone. The window protrudes slightly into the ISPR envelope so a special rear access cover has been designed to fit any NASA ISPR which goes in front of the window. ISPR standard utilities plus the Ethernet and low temperature cooling are provided at the window location. The transmittance requirements of the window are presently under development.

Centrifuge Module. The Centrifuge Module (CM), located on the zenith of Node 2, contains four ISPR type payloads and the Centrifuge rotor. Two Habitat Holding Units, a passive service system, and the Life Science Glovebox comprise the four racks required in the module. Standard ISPR type services (less the nitrogen, waste gas, and video into the rack interfaces) are provided to the active racks to support Centrifuge payload activities. Additionally, the low temperature water loop and Ethernet interfaces are provided. Potable water is required for the plants and rodents within the Habitats. The CM supports the 2.5 meter, 4 arm Centrifuge with a prime 6 kW power feed and safing power. The rotor receives moderate and low temperature water loops, 1553, Ethernet, high rate data links, and a video output. While trade studies are still being performed regarding stowage and refrigerator/freezers locations on-orbit, the CM will likely be used to support these functions and services.

Russian Research Modules. Development of the payload capabilities within the three Russian Research Module are being defined. Preliminary data reflects that the each module will have a 6.5 ft diameter x 19 ft length. The power (provide at 28 Vdc) and thermal rejection capability is envisioned to be an aggregate of 10-15 kW for all three modules. Preliminary data also reflects that an ISPR rack can not be accommodated within the modules due to their size, thus subrack interface commonality will be pursued with the Russians. Stowage availability to support payloads within the Functional Cargo Block module (FGB) is presently being determined.

EXTERNAL PAYLOAD ACCOMMODATIONS

Integrated Truss Attachments. The ISSA supports external payloads at four dedicated locations on the Starboard S3 segment and two shared locations on the Port P3 segment. The truss locations provide viewing in the ram, wake, nadir, Earth Limb, and zenith directions. Each truss site contains an automated payload attachment system used to mechanically mate the payload and an umbilical mechanism assembly to mate the utilities (Figure II). The physical attachment (completely robotic compatible) is accomplished with three guide vanes and a capture latch to secure the payload. The envelope of the truss attach sites will have a minimum payload operational envelope of 15' x 6' x 10' (a 15' x 6' attach face). The 10 foot height is based on an 11,000 pound payload with a center of gravity offset of 90" from the attachment plane. Specific allowed payload cgs will be determined on a case by case basis. Utilities are fed through the umbilical

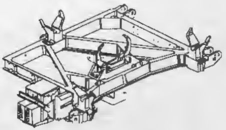

Figure II. Payload Attachment System

mechanism assembly. Power at the truss sites is provided by prime and redundant 3 kW power feeds. The voltage at the interface will be between 113 - 126 Vdc. Power is switched and circuit protected by a 25 Ampere remote power controller. Each power feed consists of 8 gauge power lines with a 12 gauge fault clearing green wire.

Each truss site is provided one remote terminal on the payload Mil-Std-1553B bus from the payload MDM in the US Lab. The bus is used for command, control, health, and status data. With the connection to the Payload MDM, downlinking of data or onboard display can be accomplished. Two high rate fiber optic data links are provided at each site. The fibers are connected directly into the automated payload switch within the US Lab to allow research data to be downlinked via the Ku-band system or switched to another payload. The data format over the high rate links is designed in accordance with CCSDS source packets and bitstream data (CCSDS 701.00-R3, June 1989).

EXPRESS Pallet. The ISSA is providing an EXPRESS Pallet capability to increase the number of payloads that can be accommodated at each truss site. The EXPRESS pallet design and performance requirements are presently under development. The preliminary requirements are for the pallet to be subdivided into six 60" x 33" adapters for payloads. The integrated pallet would support up to 6000 pounds of payloads. Power and data distribution to each of the six adapters will be provided via blind-mate connectors to the integrated pallet. The pallet will deliver up to 2.5 kW at 28 Vdc or 120 Vdc to the adapter payloads. A pallet controller will provide a Mil-Std-1553B bus, RS 422/485 and analog interfaces. It will transmit and receive high rate data on fiber optic interfaces. Payloads on the EXPRESS pallet will be robotically compatible with the Special Purpose Dexterous Manipulator by integrating an H-Handle or microconical device on the payload.

Japanese Experiment Module Exposed Facility (EF). The Exposed Facility (Figure 3) can accommodate up to 10 payloads and allows manipulation and servicing via the JEM Remote Manipulator System . The EF provides a berthing mechanism for attachment and utility distribution. The Exposed Facility Unit (EFU) is the active mechanism to allow attachment of payloads outfitted with a Payload Interface Unit (PIU). Payloads are manipulated and put in place via a Space Shuttle compatible grapple fixture. An angle correction mechanism and a fixing arm completes the alignment and physical capture task required for berthing. Each EF site accommodates a 6' x 2.6' x 3.3' payload envelope and a 1,100 pound load capability.

Utilities are fed through the EFU interface. Each site receives a 3 kW power feed between 113-126 Vdc and a 100 W safing feed. Power is switched and circuit protected with the JEM. A Mil-Std-1553B bus is provided to support command, control, health, and status of the payload. Each site is provided a moderate temperature loop for 3 kW heat rejection. The water loop is provided between 61-75 °F with a maximum return temperature of 122 °F.

As non-standard services at two sites, two 3 kW power feeds with a 6 kW thermal rejection capability are provided. Eight sites have interfaces with the high rate fiber optic bus and the NASDA video

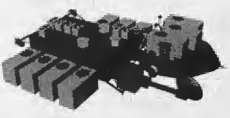

Figure 3. JEM Exposed Facility

system. The data and video services are connected back to the US Lab for downlinking distribution to the Ku-band system.

Russian Science Power Platform. Data on the Science Power Platform is maturing. The preliminary data indicates several (15) small payload accommodation sites may be available on the exterior of the science power platform. Power and data accommodations are presently under definition.

Mobile Servicing System. The Canadians are providing the robotics to support external manipulation of payloads. The Space Station Remote Manipulator System (SSRMS) allows for the installation of payloads onto the Mobile Servicing Center (MSC) for transport to the site and for integrating the payload onto the truss structure. Payloads are required to interface with the SSRMS via a grapple fixture. The SPDM, operating from the end of the SSRMS allows the manipulation and integration of small payloads onto the EXPRESS pallet.

LOGISTICS

Mini Pressurized Logistics Module. The Italian Space Agency is providing a Mini Pressurized Logistics Module (MPLM) capable of transporting 16 racks to orbit. The MPLM carries up to 20, 000 pounds of cargo and payloads. Five of the 16 rack sites have the capability to support simple payloads or refrigerator and freezer operations. These active racks are supported with 113-126 Vdc power up to 1000 Watts per rack (with the total complement of all racks not to exceed 2200 W). A Mil-Std-1553B bus is used to control the operations of these sites. A low temperature water loop (38-70° F) is used to dissipate the heat. Late access to the MPLM is provided at the launch pad for installing perishable cargo up to 80 hours prior to launch. Early access (as early as four days) is provided to the MPLM after landing of the Orbiter.

Unpressurized Logistics Carrier. An Unpressurized Logistics Carrier (ULC) is provided to transport external payloads in the Orbiter's cargo bay. The ULC can transport up to 13, 000 pounds of payload. The ULC can be integrated with Dry Cargo Carriers (DCCs) to transport small payloads. Each DCC can be outfitted with four subcarriers to transport up to 2000 pounds. Once on-orbit, the payloads can be removed from the ULC robotically. The ULC is a passive device and does not transfer power or data to the payloads.

Stowage. The ISSA is presently conducting a stowage analysis to meet the user requirement of 5 racks. Recent agreements with the Russian Space Agency has included 6-10 cubic meters of stowage within the FGB. Additionally, the program has performed a trade study for selection of a Centrifuge Module. The resources defined for the Centrifuge facility included the requirements for a -80 ° C and a -183 °C freezer. Use of a +4 °C refrigerator is available on a shared basis with the crew. A program change memo is in work to include 3 passive racks for users within the FGB (available on the first utilization flight) and for the two freezers within the Centrifuge module.

INTEGRATED VEHICLE PERFORMANCE

Microgravity. The ISSA will provide a microgravity environment to a minimum of 16 ISPR locations for at least 180 days per year in a minimum of 30 day increments. The ISSA will provide a quasi-steady acceleration magnitude of 1 micro g with a .2 micro g stability. The quasi-steady environment is obtained by the ISSA configuration and the use of control moment gyros. An active rack isolation system (ARIS) will be used to reduce the vibroacoustics levels to those required to conduct microgravity research (Figure 4). Disturbances are minimized at the ISPR locations by using the ARIS which "floats" the rack . Several actuators are driven by a control system which uses accelerometer data to position the rack. The ARIS components are configured both inside and outside the ISPR.

Power and Thermal. The ISSA will provide 26 kW minimum continuous and 30 kW average power and thermal conditioning to payloads during standard and microgravity modes of operation (approximately 300 days per year). An additional 4.5 kW of power is provided to operate ISSA systems wben supporting payload operations. During periods of high beta angles with the sun and during various other station operating modes, 6.5 kW of continuos power is provided to the integrated set of payloads. Power is generated from four sets of solar arrays on the integrated truss. Alpha joints are incorporated on the array segments for maximum sun tracking efficiency. Thermal radiators pivoting with a rotary joint dissipate heat that is transported through an internal water cooling loop system.

Data Handling and Communication. The ISSA provides an on-board command and data distribution network associated with a forward and return antenna communication link to transfer research data and video to the payload developer. A 72 kbps S-band forward link is used to send

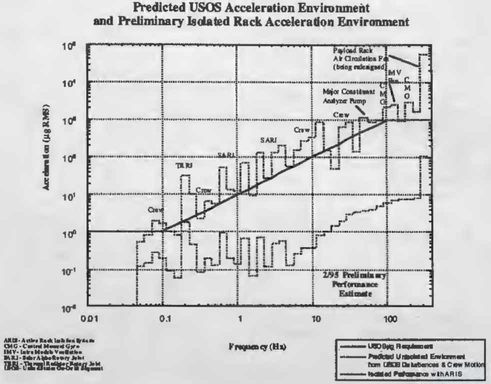

Figure 4 Expected Vibroacoustic Environment with ARIS

commands for payloads. The S-band communication coverage is estimated at 50%. Data onboard is distributed from the payloads to a prime and redundant (44 input, 36 output) automated payload switch (APS). The payload 1553 bus, the Ethernet, and high rate data links are connected to the APS. The APS selects 8 outputs for the high rate frame multiplexer (HRFM). The HRFM distributes the data to the high rate modem for distribution to the 50 Mega bit per second (Mbps) Ku-band system. The estimated coverage for the Ku-band system is a minimum of 70 %. Analyses are being performed to increase the data rate of the Ku-band system to 75 Mbps. The use of the NASDA and ESA data relay satellites is under review to provide additional S-band and Ku-band services and coverage. The Payload MDM provides 300 megabytes of non-volatile mass storage for payloads. A 116 giga bits per second (Gbps) communications outage recorder is provided to record research data during loss of signal with the communication system. Video onboard is distributed from the payload to one of several switches. The switch routes the signal to a recorder, a monitor, or for distribution to the downlink. The selection of a video compression unit (using a 20 to 1 compression scheme) is presently being studied to allow 4 channels of video to be dowulinked simultaneously with the research data.

Internal Environment Control. The atmospheric pressure nominally maintained onboard ISSA is 14.2 - 14.9

psia with a minimum pressure of 13.9 psia. Carbon dioxide levels are maintained below 0.7 % to ensure crew medical safety. To support specific biological research, agreements have been reached to lower the carbon dioxide levels to 0.37 % (with a goal to reach 0.3%) for two 90 day increments each year. This is accomplished by running several carbon dioxide removal assemblies simultaneously. The oxygen partial pressure is maintained in the range of 2.83 to 3.35 psia. Potable water is provided at a rate of 12.15 pounds per day. A waste water line is provided to the Centrifuge to support the animal and plant habitats.

Conclusion.

The International Space Station Alpha provides the research community with an infrastructure to conduct sustained space research in the life sciences, microgravity, Earth observations, astrophysics, and engineering disciplines. Several pressurized research modules and external attachment points are provided to support these disciplines. Standardization of physical and utility resources across the International Partners encourages world-wide participation and allows maximum research return on joint science ventures.

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